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Particulate air pollution, fetal growth and gestational length: The influence of residential mobility in pregnancy

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ABSTRACT

Background: It remains unclear as to whether neglecting residential mobility during pregnancy introduces bias in studies investigating air pollution and adverse perinatal outcomes, as most studies assess exposure based on residence at birth. The aim of this study was to ascertain whether such bias can be observed in a study on the effects of PM_{10} on risk of preterm birth and fetal growth restriction.
Methods: This was a retrospective study using four pregnancy cohorts of women recruited in Connecticut, USA (N=10,025). We ascertained associations with PM_{10} exposure calculated using first recorded maternal address, last recorded address, and full address histories. We used a discrete time-to-event model for preterm birth, and logistic regression to investigate associations with small for gestational age (SGA) and term low birth weight (LBW).
Results: Pregnant women tended to move to areas with lower levels of PM_{10}. For all outcomes, there was negligible difference between effect sizes corresponding to exposures calculated with first, last and full address histories. For LBW, associations were observed for exposure in second trimester (OR 1.09; 95% CI: 1.04–1.14 per 1 μg/m^3 PM_{10}) and whole pregnancy (OR 1.08; 95% CI: 1.02–1.14). For SGA, associations were observed for elevated exposure in second trimester (OR 1.02; 95% CI: 1.00–1.04) and whole pregnancy (OR 1.03; 95% CI: 1.01–1.05). There was insufficient evidence for association with preterm birth.
Conclusion: PM_{10} was associated with both SGA and term LBW. However, there was negligible benefit in accounting for residential mobility in pregnancy in this study.

1. Background

Epidemiological studies indicate that exposures to particulate matter air pollution may have adverse effects on pregnancy outcomes (Sapkota et al., 2012; Zhu et al., 2014), with fetal growth and gestational length among the outcomes commonly investigated. Most often, ground-level measurements from a government monitoring network are used to derive exposure at a single residential address, usually recorded at delivery. However, as approximately 9%–32% of women move during pregnancy there is potential for a high degree of exposure misclassification(Bell and Belanger, 2012). Patterns of residential mobility among pregnant women are largely unknown but studies indicate that moving is more likely among mothers who are younger (Canfield et al., 2006; Chen et al., 2010; Raynes-Greenow et al., 2008), have lower parity (Canfield et al., 2006; Chen et al., 2010; Miller et al., 2010), and have lower socioeconomic status (Canfield et al., 2006; Chen et al., 2010), all of whom have greater risk of delivering smaller babies and delivering preterm. Exposure misclassification might be minimal if women tend to move short distances (median, < 10 km) (Chen et al., 2010; Hodgson et al., 2009; Lupo et al., 2010). In a New York cohort, whole pregnancy exposure to particulate matter with aerodynamic diameter < 10 μm (PM_{10}) was essentially unchanged when based on residence recorded by maternal interviews (20.11 μg m^{-3}) compared to that based on the residential location recorded at delivery (20.09 μg m^{-3}) (Chen et al., 2010). In a UK cohort, annual PM_{10} derived using the residential location at delivery was highly correlated with that derived using residential locations throughout pregnancy (Pearson r=0.88) (Hodgson et al., 2015). In contrast, in another study, estimated PM_{10} exposure based on address at delivery compared to complete residential history differed by more than one standard deviation in 16% of pregnancies (Hodgson et al., 2015). Consequently, it remains unclear as to whether final effect estimates on preterm birth and fetal growth restriction are biased by ignoring residential mobility in the derivation of PM_{10} exposure (Chen et al., 2010; Lee et al., 2013; Pereira et al., 2013, 2014a, 2014b, 2015).

The aim of this study was to compare effect estimates of

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particulate matter (PM_{10}) exposure on fetal growth and gestational length, with and without accounting for residential mobility using four large pregnancy cohorts in Connecticut, between 1988 and 2008.

2. Methods

2.1. Study design and setting

This was a retrospective study using four pregnancy cohorts of women recruited in Connecticut, USA (N=10,025). Women were interviewed 2–4 times in pregnancy. Women were recruited at < 25 weeks gestation for the Asthma in Pregnancy study (Triche et al., 2004) (AIP; 1996–2000; N=2255) and the Pink and Blue study (Spoozak et al., 2009) (PAB; 2005–2008; N=2645) of depression in pregnancy. Women were recruited at < 16 weeks gestation for the Nutrition in Pregnancy study (Bracken et al., 2003) (NIP; 1996–1999; N=2344) and Environmental Tobacco Smoke study (Sadler et al., 1999) (ETS; 1988–1991; N=2781). Further details of the cohorts have been published previously (Triche et al., 2004; Spoozak et al., 2009; Bracken et al., 2003; Sadler et al., 1999).

2.2. Participants

We excluded women with at least one address that could not be geocoded (N=182). We sequentially excluded records with multiple gestations (N=165), missing sex (N=55), and records with missing gestational age (N=1) or gestational age > 42 weeks (N=35), which resulted in a study population of 9587 singleton pregnancies. Women were not explicitly asked for their residential histories. Day of residential move was ascertained in the course of cohort follow-up from the point of contact at recruitment to the post-partum interview.

2.3. Outcome variables

Preterm birth (PTB) was defined as birth before 37 completed weeks of gestation. Period of gestation was obtained from the birth certificate record. This was the clinical best estimate of gestational age, based on ultrasound or last menstrual period if ultrasound was not available. Births were classified as small for gestational age (SGA) if birth weight was < 10th centile for gestational age and sex (Oken et al., 2003). Term low birth weight (LBW) was defined as a birth with at least 37 weeks of completed gestation attaining a birth weight < 2500 g.

2.4. Exposure variables

Daily PM_{10} measurements from the US Environmental Protection Agency (EPA) monitoring network were obtained for all monitors within 100 km of participants' residential addresses. We calculated exposure using measurements from monitors within circular “buffer” radii of 20 km, 40 km, and 100 km from the residential address. At each residential location and gestational week of pregnancy we calculated the 7-day average PM_{10} concentration using (i) measurements from the closest monitor to the residential location within the buffer distance, and (ii) the inverse distance weighted (IDW) average of measurements from all monitors within the buffer distance. These weekly means were then used to compute average PM_{10} concentrations for each trimester (< week 14, weeks 15–26, > week 26) and for the whole pregnancy. By definition, pregnancies are not at risk of preterm birth after gestational week 36. For this reason, only measurements prior to either birth or gestational week 36 (whichever was earlier) were included in the calculation of third-trimester and whole-pregnancy exposures for the preterm birth analyses. To ascertain the effects of acute exposure on the risk of preterm birth, we calculated mean PM_{10} exposure for the week of delivery and the 6-week period prior to delivery. We calculated exposures using (i) the address at recruitment (first address), (ii) the address at delivery (last address), and (iii) all addresses updated throughout pregnancy (updated addresses).

Table 1
Maternal characteristics at study entry.

	N women	%
Age		
< 20 years	575	6
20–24 years	1120	12
25–29 years	2623	27
30–34 years	2807	29
35–39 years	1503	16
40+ years	243	3
Missing	812	8
Race/ethnicity		
White	7337	76
African American	721	7
Hispanic	1241	13
Asian	183	2
Other	190	2
Missing	11	0
Marital status		
Married	7418	77
Single	2003	21
Divorced/separated	260	3
Missing	2	0
Education (highest level)		
Did not complete High School	819	8
Completed High School	1601	17
Post-secondary	4864	50
Graduate and Above	2394	25
Missing	5	0
Parity		
No children	4251	44
1 child	3522	36
2 children	1419	15
≥ 3 children	491	5
Pre-pregnancy weight		
< 56 kG	2432	25
56–62 kG	2328	24
63–72 kG	2556	26
≥ 73 kG	2202	23
Missing	165	2
Smoking in pregnancy		
Smoked tobacco	1657	17
Missing	1074	11
Alcohol consumption in pregnancy		
Consumed beer, wine or liquor	4184	43
Missing	4	0
Cohort		
AIP	2169	22
ETS	2688	28
NIP	2213	23
PAB	2613	27